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SMART INTERFACES FOR DECISIVE COUNTERSPACE OPERATIONS

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FINAL REPORT FOR THE PERIOD JUNE 2002 TO MAY 2004

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

//Signed//

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14. ABSTRACT

Satellites are critical assets to our national security thus making them tempting targets for adversaries. Unfortunately the lack of tools that provide situational awareness on the ground makes the process of identifying and classifying many types of attacks difficult at best. Research in "smart" man-machine interfaces for counterspace operations has been performed at the Air Force Research Laboratory to improve the warfighter's ability to gain situational awareness during satellite attacks. Preliminary studies have shown a considerable decrease in time and errors by using technologies such as intelligent agents, speech input, and 3-D displays.

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Executive Summary

Abstract: Satellites are critical assets to our national security thus making them tempting targets for adversaries. Unfortunately the lack of tools that provide situational awareness on the ground makes the process of identifying and classifying many types of attacks difficult at best. Research in "smart" man-machine interfaces for counterspace operations has been performed at the Air Force Research Laboratory to improve the warfighter's ability to gain situational awareness during satellite attacks. Preliminary studies have shown a considerable decrease in time and errors by using technologies such as intelligent agents, speech input, and 3-D displays.

Keywords: human-machine interface, supervisory control, satellite control, pattern recognition, displays.

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1. SATELLITE ATTACK IDENTIFICATION

According to Robert Dickman, deputy for military space in the Office of the Undersecretary of the Air Force, the US is "beyond the point where we can successfully prosecute a war without space systems and that is not lost on our adversaries." He also points out that currently fielded capabilities make it "very hard to tell" when a satellite is under attack [Koch, 2003]. One reason for this situation is that many satellites have limited sensor capabilities to detect threats. But even if sensors pick up signs of an attack, they could easily go unnoticed or misinterpreted on the ground.

Piecing together the clues to detect and assess an attack can be quite arduous with the tools used by satellite controllers and analysts today (Figure 1) [Grossman, 2003]. Air Force satellite control centers use antiquated technology requiring multiple human controllers per satellite, each viewing alphanumeric displays that degrade situational awareness (SA), increase crew workload and invite confusion during demanding wartime scenarios [Sharkey, et al 2002].

The stakes are high for single satellite attacks but they may be much higher if multiple satellites are attacked. There clearly is much more to be gained from simultaneous attacks because a loss of one satellite may not have a significant impact for many missions. A "space Pearl Harbour" situation would require central agencies such as Air Operations Centers (AOCs), the North American Aerospace Defense Command (NORAD) and United States Strategic Command (USSTRATCOM) to maintain solid SA of the entire battlespace in near real-time [AFSPC, 2000; USSPACECOM, 2000]. Advances in human-computer interfaces and automation can allow such organizations to achieve SA quicker but these technologies have unfortunately not been effectively applied in most cases.

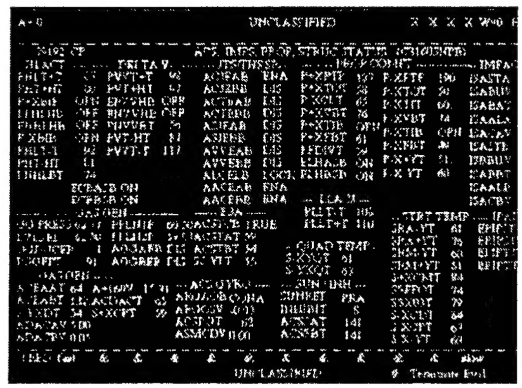

Figure 1: Example of a satellite operator screen. These "old school" displays employ confusing mnemonics and ineffective use of color.

2. HUMANS AND AUTOMATION

The military is developing methods to automatically recognize signs of an attack [Hanson, 2004]. In some cases, it may be necessary for satellites to autonomously react to threats since there would not be enough time for human's to react. Full automation, however, is often not cost effective plus certain scenarios will call for some degree of human judgment. Programmed logic can not always deal with changing world events or understand political consequences of actions taken.

Automation can be a great tool to assist humans. It can help user's deal with their limitation such as their:

- Inability to rapidly process data.
- Difficulty handling large data sets.
- Difficulty fusing data.
- Difficulty recognizing subtle trends.
- Difficulty maintaining a chain of thought.

Well-designed automation can allow the user to think at the decision level and request details when desired. Before decisions can be made however, humans must understand the situation that they are dealing with. This is often tougher to accomplish than one might expect. Typically space analysts were forced to maintain mental models as their sole representation for understanding. Mental models, however, have limitations and increase cognitive demands [Johnson-Laird, 1983]. Interfaces that graphically depict the real world can be effective at quickly raising a user's situational awareness.

Helping users maintain a chain of thought is often overlooked in interface design. Dealing with cumbersome user interfaces or sorting through information that arrives at inconvenient times can be counterproductive. In the real world of dynamic complexity, information does not usually arrive to an operator neatly packaged in

task-by-task bundles, but rather multiple streams of information exist, and these are often interleaved in time. Smart interfaces are being developed in various domains to deal with this problem [Skelly, 2003].

Table 1 adapted from Sheridan [1992] breaks automation out into ten discrete levels. Note that levels 7 through 10 do not give the human any say in task execution. However situations that involve an attack to our national assets, a human will likely need to be made aware of the situation as quickly as possible and, time permitting, be given the ability to at least veto an autonomously suggested action. Research has been conducted to help warfighters in counterspace operations. Some of this research will be discussed in the following sections.

Table 1 Levels of Automation

Level	Action performed by the computer.
HIGH 10	Decides everything and acts without human involvement
9	Informs human only if the computer decides to
8	Informs human only if asked to
7	Executes automatically then must inform human
6	Allows human a restricted time to veto before automatic execution
5	Executes the suggestion if human approves
4	Suggests one alternative
3	Narrows selection down to a few
2	Offers a complete set of alternatives
1 LOW	Offers no assistance: human makes all decisions and performs all actions

3. SMART INTERFACES

Starting in 2003, the Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Interface Division (AFRL/HEC), under a program titled Smart Interfaces for Decisive Counterspace Operations (SIDCO), investigated methods to improve an analyst's ability to identify a satellite attack. The SIDCO effort involved developing software to shorten the time to identify an attack, reduce erroneous identifications and lessen job frustration (Figure 2). Erroneous identifications include reporting an attack for an unintentional action, or worse, reporting "no attack" when one actually has occurred.

The baseline for SIDCO was driven by the Defensive Counterspace Testbed (DTB) project developed by the Center for Research Support (CERES) at Schriever Air Force Base,

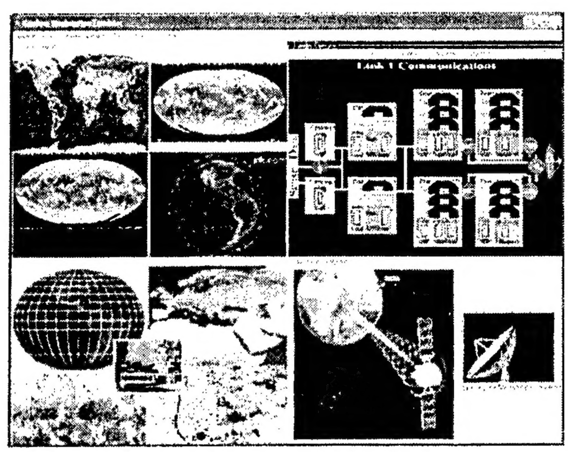

Figure 2: SIDCO user display.
Included 3-D views of satellites as specified by the user plus other relevant information such as satellite subsystem status and weather. Note however that visual displays were not the focus of this effort.

Colorado [Hessin, 2001]. DTB employed the commercial off-the-shelf software package Satellite Tool Kit (STK) by Analytic Graphics, Inc. Although the graphical two- and three-dimensional displays provided by STK made it easier to visualize the battlespace, it was considered by some at CERES to be too time-consuming and mentally demanding to use in high-stress situations.

3.1 Speech Interface

It was therefore determined, in discussions between CERES and AFRL/HEC, that a speech interface should be added to DTB. This speech interface was to encapsulate multiple STK and windowing commands into logical phrases that could be spoken by the operator.

A limited set of commands were proposed by CERES as a starting point for this effort. Examples of these commands were:

- Window2D * Iconify 1
  Spoken: "minimize STK view one"
- Window3D * Iconify 2
  Spoken: "minimize VO view two"
- Window3D Scenario/* Raise 2
  Spoken: "restore STK view two"
- SetTimePeriod Scenario/* "now" "+1440 minutes"
  Spoken: "ahead fourteen forty minutes" or
  "ahead one-four-four-zero minutes"
- VO Scenario/* 3dView Eye FromTo Satellite/6451 3
  Spoken: "focus on satellite sixty-four fifty-one in three"
- VO Scenario/* 3dView Eye FromTo Facility/CTSC 4
  Spoken: "focus on facility CTSC in four"
- DisplayTimes */Satellite/6451/Sensor/Sensor-6451_Downlink State AlwaysOn
  Spoken: "display times for satellite sixty-four fifty-one on"
- Graphics Scenario/*/Satellite/6451/Sensor/ Sensor-6451_Downlink SetColor white
  Spoken: "color satellite sixty-four fifty-one white"
- Animate Scenario/* Start RealTime Continuous
  Spoken: "animate start"
- Graphics */Satellite/Debris6 Label ON
  Spoken: "label satellite sixty-four fifty-one on"
- Access */Satellite/6451 */Satellite/1234 On On On
  Spoken: "show access times between satellite sixty-four fifty-one and satellite twelve thirty-four"
- RemoveAllAccess /;Animate * Reset
  Spoken: "remove all access"
- VO */Satellite/6451 AttitudeView Sphere Show On
  Spoken: "attitude sphere for satellite sixty-four fifty-one on"
- VO */Satellite/6451 VectorAxes Modify "LVLH" Axes Object Show ON
  Spoken: "set satellite sixty-four fifty-one in view one set vector axes on" or "set satellite sixty-four fifty-one in view three topocentric on"

Notice that some of these were actually fairly complex STK commands or multiple steps that were encapsulated into one logical spoken command. Also notice there were some flexibility in the spoken commands. For example, the number 6451 could be spoken as "six-thousand four-hundred fifty-one," "sixty-four fifty-one" or "six-four-five-one." The goal was to minimize cognitive processes necessary to navigate the software.

3.2 *Intelligent Agents*

After much of the speech interface was developed, it was determined that automation beyond speech recognition should be provided to the user. Therefore the SIDCO team implemented a functional demonstration of intelligent agent technology to off-load some of the data gathering tasks that often distracted analysts from their ultimate goals. Although some of the intelligence functionality was hard-coded into SIDCO for experimental purposes, the capability nonetheless was real. SIDCO agents were set up to answer specific questions such as "Did the anomaly occur over unfriendly territory?"

Fully functional agents are essentially virtual assistants built with artificial intelligence programming techniques. They operate steady state until the data they continually monitor indicates parameters are out of bounds. Their role then is to gather information and, if necessary, work collaboratively with other agents or humans to suggest possible causes, whether it was a system malfunction, an act of aggression or other cause.

It is envisioned that the agents would not blindly seek information; rather they would make some interpretations about what the data could be implying then apply this knowledge to seek additional data. For example if one piece of data suggested a certain type of attack, then the agent would first seek additional evidence to support that theory before gathering information to support other theories.

In addition to suggesting probable scenarios supported by their knowledge base, agents can work collaboratively with the user to draw their own conclusions. For example, a simple collaborative operation could start with the user requesting a trend analysis of data over a specific timeframe. Having collected and fused the data and exhausted further reasoning actions as described in the knowledge base, the SIDCO agents report their findings, including the probably cause, and facilitate in additional analyses if the user desires.

The agents were developed to answer the questions shown in Figure 3 – the experimental logic flow for the pilot study (described in the following section). This greatly simplified the analysis process but the users were also required to verify the answers using the STK speech input and visualizations. Although the agents did not give wrong answers in this study, the subjects in the pilot study were not told that the agents would be accurate in all cases.

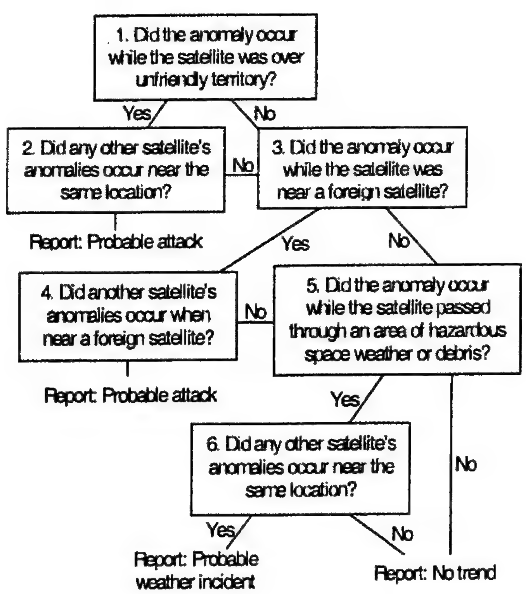

Figure 3: SIDCO Experiment Flow.
The users followed this logic to determine whether the anomaly was due to an attack, space weather or something else. For experimental purposes, this logic was a greatly simplified version of a much more involved analysis process.

Although not implemented in this version of SIDCO, future versions should allow the user to interrupt the agent at any time to determine what had been learned so far. This is important in time-critical situations where it may not be practical to let the agent fully complete its task.

3.3 *Evaluation*

It was not possible to run a statistically significant study to show the effectiveness of SIDCO given budget and schedule constraints. However a small pilot study was conducted to determine if further research and development was warranted. Six subjects between the ages of 18 and 55 participated. They were required to have experience with the Microsoft Windows operating system but no other experience was required. None of the subjects had previous experience with STK or satellite operations.

The subjects were split into two groups: one group was permitted to use SIDCO functionality (SIDCO-On), the other was not (SIDCO-Off). The overall objective was for participants to differentiate between a satellite attack, an internal system glitch and a space weather incident. The participants received an indication that a satellite's health had been compromised, then proceeded to determine whether the satellite was indeed under attack. The subjects

followed specific procedures and guidelines to determine attack validity. These procedures were driven by a script developed by Sytronics, Inc. and were varied depending on the scenario workflow.

Four different workflow scenarios were presented in random order to each group. The logic flow in Figure 3 was used as the basis for the scenarios. Essentially the operator needed to determine whether the anomaly occurred while the satellite was over friendly territory. The assumption here is that an enemy could perform a ground attack from their own territory. If this turned out to be true, then the subject would need to determine if other satellites had problems near the same location. If this also turned out to be true, then it was to be reported that an attack was likely originating from a terrestrial threat. If this was not the case, the subject then needed to determine if there was a threat from a foreign satellite. If more than one satellite experienced an anomaly while near a foreign satellite, then the subject was to report that an attack from an orbital source.

If a space-based attack also seemed unlikely, then the subject attempted to determine if the incident was due to space weather. It was assumed that adverse space weather affected satellites within a limited proximity relative to both time and space. If the conditions for a space weather incident also failed, it was to be reported that there was no trend. As stated earlier, the subjects were presented with four different workflow scenarios. Scenario 1 was a ground attack, Scenario 2 was a space attack, Scenario 3 was no trend, and Scenario 4 was weather. The results of the preliminary study are provided in Figures 4 and 5. The results seem to indicate a strong improvement with the intelligent agents and speech interfaces.

4. FUTURE WORK

4.1 Work-Centered Support System

To continue research in counterspace tools for the warfighter, three Small-Business Innovative Research (SBIR) projects started in May 2004 to apply work-centered support concepts [Eggleston and Whitaker, 2002] to the counterspace problem. Work-Centered Support Systems (WCSS) have been successfully demonstrated for other Air Force operations but not yet for space.

A WCSS differs from traditional human-computer interface development in that it is focused on the user's problem workspace and provides multiple forms of work aids within a unified cognitive support framework (Figure 6).

In addition to improved user interfaces, the WCSS provides a systematic method to integrate intelligent agents that work cooperatively with humans and other software agents in the gathering and fusing of information [Scott, et al, 2003; Young, et al, 2001].

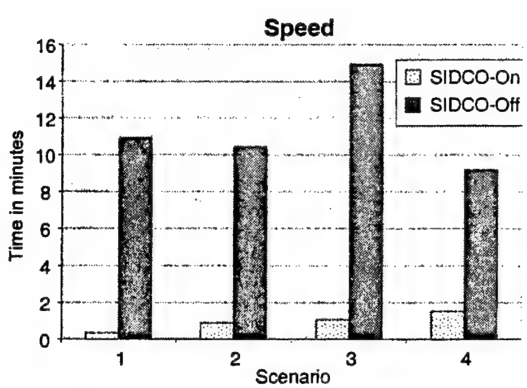

Figure 4: SIDCO Preliminary Speed Results. This graph shows the average time to complete each of the 4 scenarios with SIDCO-On and SIDCO-Off.

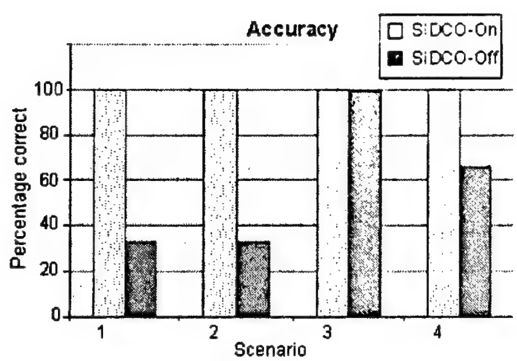

Figure 5: SIDCO Preliminary Accuracy Results. This graph shows the accuracy (% correct) of answers with SIDCO-On and SIDCO-Off.

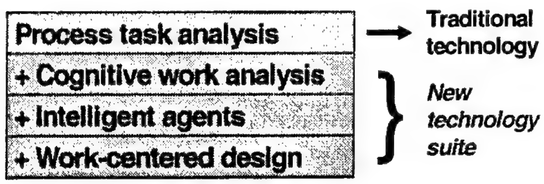

Figure 6: Work-Centered Support System (WCSS). Developing a WCSS involves analyzing the work processes and cognitive activities [Vicente, 1999] as they unfold in a complex work situation before applying intelligent agents and work-centered design concepts.

At the request of the analyst, the WCSS will be aimed at intelligently surveying historic and current data of individual satellites, entire constellations and other relevant sources. In addition to recognizing threats and attacks, the system should help operators identify non-intentional system degradation that may have otherwise been difficult to identify.

There are several groups of people involved in counterspace operations who may be targeted for this work including satellite operators/engineers, Air Operations Centers (AOCs), United States Strategic Command (USSTRATCOM), and the National Military Command Center (NMCC). Seemingly all of these organizations will need to gain situational awareness during a satellite attack but all will probably have some unique requirements as well. The WCSS process could help to determine what these requirements are and how interfaces can be developed to address their unique and common needs.

4.2 Advanced Displays

Immersive displays, like those used for training simulators and arcade games, have been shown to aid in situational awareness [Bush, 2004]. Many people have observed that a 10-year old can gain SA in a video game so it seems that those concepts could be applied to space SA.

Therefore other future research may involve immersive displays such as the Cave Automatic Virtual Environment (CAVE) by Fakespace Systems, Inc [DeFanti, 1993]. Stereo images, such as those from STK, would be projected on the walls and floor of this room-sized cubical. Several persons wearing lightweight stereo glasses would be able to share the immersive experience and possibly gain a better understanding of events in the orbital battelespace. Other immersive solutions all may be explored such as head-mounted displays with full-body tracking.

5. CONCLUSIONS

For many reasons discussed in this paper we cannot rely totally on automated methods to identify every possible threat or attack to a satellite system. Automation can, however, be an invaluable tool to allow humans gather, fuse and process information during these high-stress situations. Humans will continue to be a critical element in the satellite threat warning/attack reporting process for the foreseeable future.

Although only a trial study could be run, the functionality demonstrated by SIDCO shows considerable promise to improve satellite attack identification with respect to both time and accuracy. Work in WCSS, starting in mid-2004, will take another angle on counterspace interface development. It is possible that this research in addition to wargames could help us determine what new sensors will be needed and what data they will need to supply. In any case, human interfaces should be considered early in the development of our counterspace capability.

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Apppendix A: Initial SIDCO Grammer

Below is the grammar for the Space Situational Awareness speech recognition system. At this point this is a wish list so not all commands will be implemented. Optional elements are depicted with [brackets] or with shading. Variable elements (such as number values or names) are *italicized*. Words with synonyms are in **bold** which are further explained at the footer.

show	[all]	• **satellites** • **systems**	• **with**		• abnormal [readings | states] • low [power level | ...] • high [power level | ...]
show	[all]	• **satellites** • **systems**	[not]	• near • facing • over • in	• [satellite] *name* • Earth • *location on or in relation to the Earth* • *airborne object* • [ground station] *name* • the sun • [orbit] *name*
show	• [TT&C] downlink [status] • [TT&C] uplink [status] • **system** [status] • bad **systems** • altitude • attitude • [all] [objects | **satellites**] within *integer* [km | miles] [of]	• [constellation] *name* • [**satellite**] *name* • [**system**] *name* • [ground station] *name* • Earth • *location on or in relation to the Earth*	[and]	• [constellation] *name* • [**satellite**] *name* • [**system**] *name* • [ground station] *name* • Earth • *location on Earth*	
show	• local satellite time • Earth **satellite** sun angle • solar intensity • attitude sphere • [orbit] position | velocity • antenna azimuth [and elevation angles] • antenna azimuth [and elevation angles] • mode [in which] RGF antenna [is being driven] • [if | indication of whether] waveguide switch is directing energy to antenna • if commanding is [enabled | disabled] • radiate enable control readback • RGF range value • status of range data quality bit • **IRIG day | IRIG hour | IRIG minute | IRIG second | PMER | YMER | RMER | PRPSPD | PRMSPD | PYPSPD | PYMSPD | TIOIN1 sync | VCC1 | ZZGCC**	[for]	• [**satellite**] *name*		
hide	• [**satellite**] *name* • [window] *name* • [constellation] *name*	• **with** • in window	*name*		
go to	• *absolute time (e.g., 0500 GMT)* • *time marker (e.g., when anomaly occurred)*				
backup	• *relative time (e.g., 4 minutes)* • *time marker*				
[tile | cascade | split]	[windows | screen]				

Synonyms for this grammar:
show: show me [the] | [let me] view [the] | display [the] | [let me] see [the]
hide: get rid of | remove
with: that have | exhibiting | displaying | containing
satellite: sat | spacecraft | space asset | vehicle | bird
system: subsystem | component
go to: rewind back [to] | go back | backup [to]
backup: backup to | rewind back [to] | go back | backup [to]

IRIG day:	Julian Day *(will display full date & time)*
IRIG hour:	Hour *(will display full date & time)*
IRIG minute:	Minute *(will display full date & time)*
IRIG second:	Second *(will display full date & time)*
PMER:	Pitch Momentum Equivalent Rate
YMER:	Yaw Momentum Equivalent Rate
RMER:	Roll Momentum Equivalent Rate
PRPSPD:	Pitch/Roll + Reaction Wheel Speed
PRMSPD:	Pitch/Roll - Reaction Wheel Speed
PYPSPD:	Pitch/Yaw + Reaction Wheel Speed
PYMSPD:	Pitch/Yaw - Reaction Wheel Speed
TIOIN1_SYNC:	Telemetry indicator | if telemetry is being received
VCC1:	Vehicle command count, downlink
ZZGCC:	Ground command count, uplink

Apppendix B: SIDCO Evaluation Plan

Six volunteers will participate in the SIDCO evaluation. The volunteers will be Sytronics' employee between the ages of 18 and 55. All will have experience with the Windows operating system. No other experience will be required. None will have previous experience with STK.

Three of the volunteers will participate with SIDCO-Off. The other three will participate with SIDCO-On. Four different workflow scenarios will be presented to each of the three participants in each of the SIDCO-On/SIDCO-Off groups. The order in which they receive the scenarios will be randomized. Each volunteer will be briefed on what the evaluation is about and what they will be tasked to do throughout the evaluation. The SIDCO-Off session will last approximately ½ hour. The SIDCO-On session will last approximately 1 ½ hours. The volunteers in the SIDCO-OFF Group will be offered a 10 minute break approximately 45 minutes into the session.

The task will be for participants to determine satellite attack using SIDCO software and procedures. The participant will receive a threat that a satellite's health has been compromised, and the subject will need to determine whether the satellite is indeed under attack or if the problem lies elsewhere. The subject will follow specific procedures and guidelines to determine attack validity. These procedures will be driven by a script developed by Sytronics and will vary depending on the scenario workflow.

Figure B1 shows the logic flow for the scenarios. The scenarios are defined by the table below the logic flow.

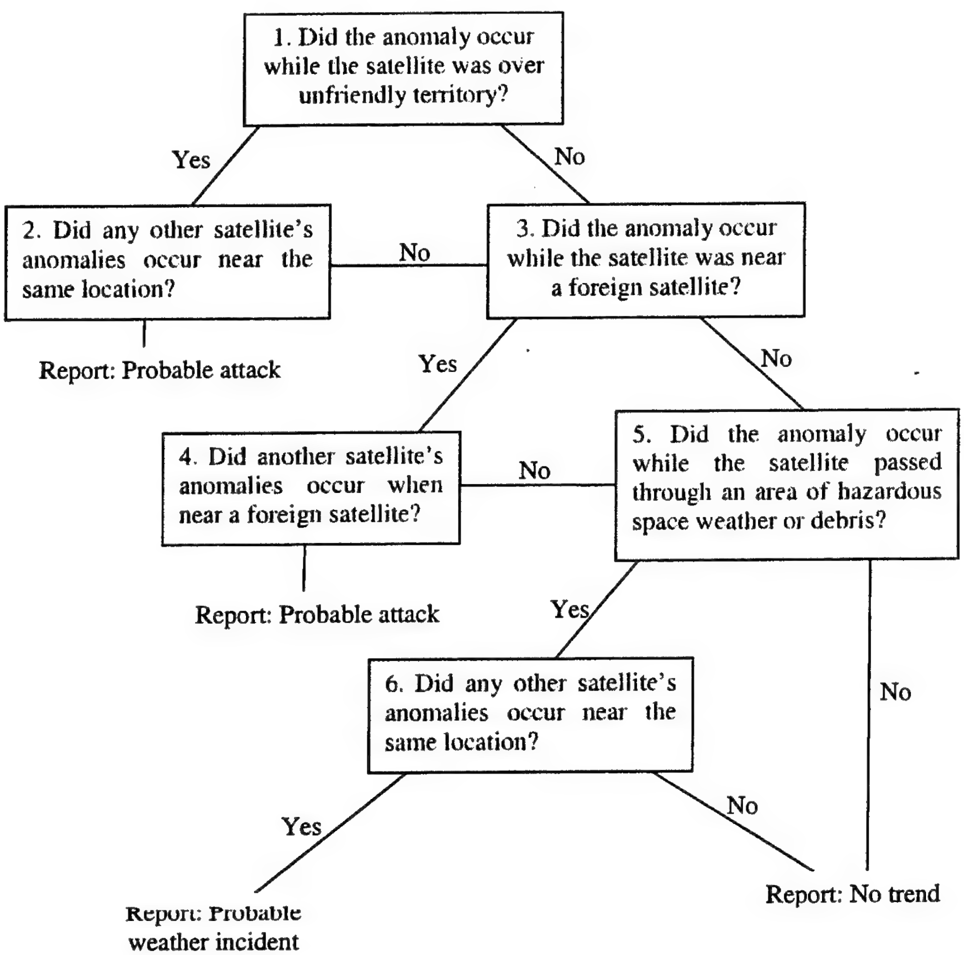

Figure B1: Experiment logic flowchart

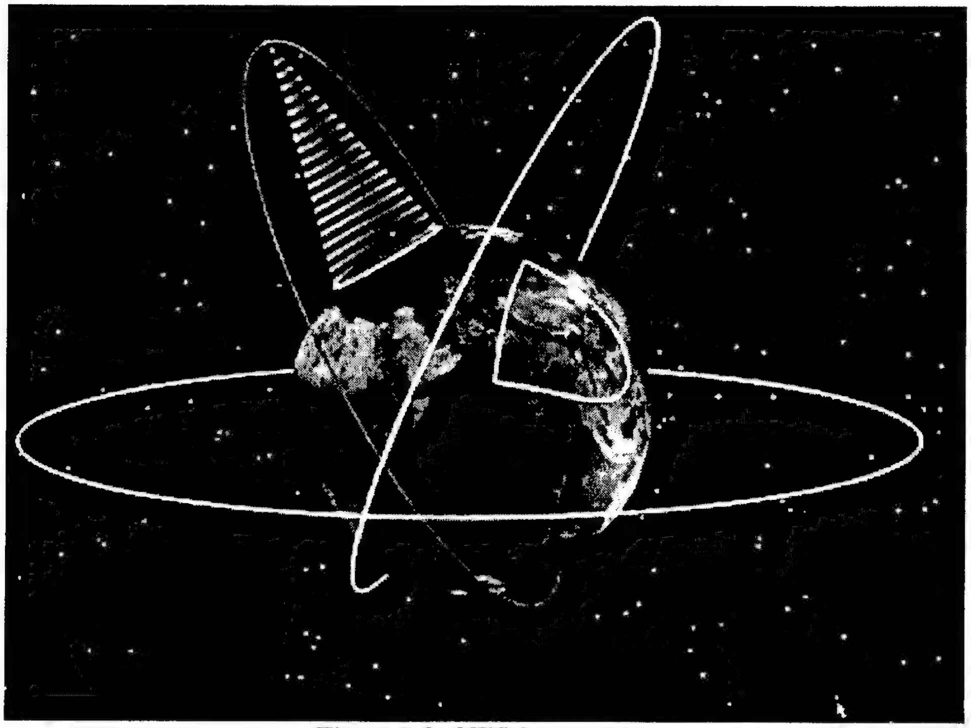

Figure B2: STK Screenshot

Scenarios

Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Workflow Step	Result	Workflow Step	Result	Workflow Step	Result	Workflow Step	Result
1	Y	1	Y	1	Y	1	Y
2	Y	2	N	2	N	2	N
		3	Y	3	Y	3	Y
		4	Y	4	N	4	N
				5	N	5	Y
						6	Y
Answer	Attack	Answer	Attack	Answer	No Trend	Answer	Weather

Scenario Order

SIDCO-On			SIDCO-Off		
Volunteer 1	Volunteer 3	Volunteer 5	Volunteer 2	Volunteer 4	Volunteer 6
4	2	3	1	3	2
3	3	1	4	1	1
2	1	2	2	4	4
1	4	4	3	2	3

The following is a checklist that the SIDCO-Off Volunteers were instructed to follow. The number of steps required to complete the task was dependent on the workflow scenario.

SIDCO_OFF_CHECK_LIST

Instructions
1. Did the anomaly occur while the satellite was over unfriendly territory?
1.1 Select "Intel" from the ODrS pull down menu.
1.2 Check "Where is Unfriendly territory" box.
1.3 Click "Submit" and wait for unfriendly territory information to appear in the cache.
1.4 Click "rocky" from the friendly satellite cached information.
1.5 Click "Tools" from the "STK_GUI" toolbar.
1.6 Click "Report".
1.7 Click "ECF LLR Position" report.
1.8 Click "Create".
1.9 Close STK Report Tool window
1.10 In the ECF LLR Position report scroll down to the date and time of the anomaly.
1.11 If satellite "rocky's" LAT and/or LNG is within +/- 5 degrees of any unfriendly territory, then anomaly occurred over unfriendly territory
1.12 Answer the question by clicking "Yes" or "No" in the "Work Flow 1 - Response" dialog window
1.13 Close the "ECF LLR Position" report window.
2. Did any other satellite's anomalies occur near the same unfriendly territory?
2.11 Select satellite "bullwinkle" from the "friendly satellites" in the the cache.
2.12 Click "Tools" from the "STK_GUI" toolbar.
2.13 Click "Report".
2.14 Click "Yaw Pitch Roll".
2.15 Click "Create".
2.16 In the "Yaw Pitch Roll" report scroll down to the date and hour of the anomaly.
2.17 A satellite anomaly occurred if Pitch, Yaw, and Roll = 0.
2.18 If not equal to 0, then close the report window and repeat steps 2.11 through 2.17 using satellite "noaa".
2.2 Close the STK report
2.3 Answer the question by clicking "Yes" or "No" in the "Work Flow 2 - Response" dialog window
2.4 Close the "Yaw Pitch Roll" report window.
3. Did the anomaly occur while the satellite was near a foreign satellite?
3.1 Select "Intel" from the ODrS pull down menu.
3.2 Check "Foreign satellites in the area" box.
3.3 Click "Submit" and wait for unfriendly satellite information to appear in the cache.
3.4 Click "Tools" from the "STK_GUI" toolbar.
3.5 Click "Access" from the pull down menu.
3.6 Type "Satellite" "rocky" in the "From" fields (IMPORTANT: Case Sensitive).
3.7 Type "Satellite" "boris" in the "To" fields (IMPORTANT: Case Sensitive).
3.8 Click "Get ACCESS Times" button.
3.9 Scroll down to the date and approximate time of Satellite Rocky's anomaly.
3.10 If approximate access times fall within 1 hour of Rocky's anomaly, then anomaly occurred while near a foreign sat.
3.11 When finished click "Remove All Access".
3.12 Click "Cancel" in the "Report" dialog.
3.13 Answer the question by clicking "Yes" or "No" in the "Work Flow 3 - Response" dialog Window
4. Did another satellite's anomalies occur when near a foreign satellite?
(Use STK and the following commands to view a simulation of satellite orbits and access between friendly and unfriendly satellites)
(a line will be drawn between two satellites when those satellites have "access" to each other)
4.1 Click "Window" from the STK_GUI toolbar.
4.2 Click "Restore all STK views" from the pull down menu.

Instructions
4.3 Click "Animation" from the "STK_GUI" toolbar.
4.4 Click "Animate Sequence" from the pull down menu.
4.5 Select the June 7th animation (An STK animation will appear)
4.51 Click "Window" from the STK_GUI toolbar then Click "Hide Satellite Rocky" from the pull down menu.
4.52 Click "Window" from the STK_GUI toolbar then Click "Hide Satellite Bullwinkle" from the pull down menu.
4.53 Click "Window" from the STK_GUI toolbar then Click "Ahead ten minutes" from the pull down menu
4.54 Click "Animation" from the STK_GUI toolbar then Click "Start" from the pull down menu.
4.55 Click "Window" from the STK_GUI toolbar then Click "Backup six minutes" from the pull down menu.
4.56 Click "Animation" from the STK_GUI toolbar then Click "Start" from the pull down menu.
4.57 Click "Animation" from the STK_GUI toolbar then Click "Pause" from the pull down menu.
4.58 Click "Window" from the STK_GUI toolbar then Click "Display Satellite Rocky" from the pull down menu.
4.59 Click "Window" from the STK_GUI toolbar then Click "Display Satellite Bullwinkle" from the pull down menu.
4.591 Click "Animation" from the STK_GUI toolbar then Click "Reset" from the pull down menu.
4.592 Click "Window" from the STK_GUI toolbar then Click "Minimize all STK views" from the pull down menu.
4.6 Select "bullwinkle" from the "friendly satellites" in the cache.
4.7 Click "Tools" from the "STK_GUI" toolbar.
4.8 Click "Report" from the pull down menu.
4.9 Select "Yaw Pitch Roll" report.
4.10 Click "Create".
4.11 Close the STK Report Tool Window
4.12 Click "Tools" from the "STK_GUI" toolbar.
4.13 Click "Access" from the pull down menu.
4.14 Type "Satellite" "bullwinkle" in the "From" fields (IMPORTANT: Case Sensitive).
4.15 Type "Satellite" "boris" in the "To" fields (IMPORTANT: Case Sensitive).
4.16 Click "Get ACCESS Times" button.
4.17 In the "Yaw Pitch Roll" report scroll down to the date and hour of the anomaly.
4.18 Another satellite's anomaly occurred if Pitch, Yaw, and Roll = 0. If not 0, then go to step 4.19 else go to step 4.20.
4.19 Close the Access report and repeat steps 4.6 through 4.18 using satellite "natasha"
4.20 Close the "Yaw Pitch Roll" report.
4.21 Close the "Access" report
4.22 Answer the question by clicking "Yes" or "No" in the "Work Flow 4 - Response" dialog window.
5. Did the anomaly occur while the satellite passed through an area of hazardous space weather or debris?
5.1 Select "Space Weather" from the ODrS pull down menu.
5.2 Check "What is the space weather like" box.
5.3 Click "Submit" and look at the space weather data returned in the cache information window.
5.4 Answer the question by clicking "Yes" or "No" in the "Work Flow 5 - Response" dialog window
6. Did any other satellite's anomalies occur near the same space volume?
6.1 Select "Space Weather" from the ODrS pull down menu.
6.2 Check "Any other satellites affected by the weather" box.
6.3 Click "Submit" and look at the NOAA information returned in the cache.
6.4 Select "bullwinkle" from the friendly satellites in the cache.
6.5 Click "Tools" from the "STK_GUI" toolbar.
6.6 Click "Report" from the pull down menu.
6.7 Select "Attitude Quaternions" report.
6.8 Click "Create".
6.9 Close the STK Report Tool Window.
6.10 In the "Attitude Quaternions" report scroll down to the date and hour of the anomaly.
6.11 A satellite anomaly occurred if q1, q2, and q3 = 0. If not 0, then repeat steps 6.4 through 6.9 using satellite "noaa".
6.12 Answer the question by clicking "Yes" or "No" in the "Work Flow 6 - Response" dialog window.
6.13 Close the "Yaw Pitch Roll" report window.

The Following is a Checklist that the SIDCO -On volunteers were instructed to follow.

SIDCO_ON_CHECK_LIST

Instructions
Say "Did the anomaly occur while the satellite was over unfriendly territory"? (Wait for the statement to appear before saying "OK")
Say "OK"
Say "Did any other satellite's anomalies occur near the same unfriendly territory"? (Wait for the statement to appear before saying "OK")
Say "OK"
Say "Did the anomaly occur while the satellite was near a foreign satellite"? (Wait for the statement to appear before saying "OK")
Say "OK"
Did another satellite's anomalies occur when near a foreign satellite?
(Use STK and the following commands to view a simulation of satellite orbits and access between friendly and unfriendly satellites)
(a line will be drawn between two satellites when those satellites have "access" to each other)
Say "Restore all STK views"
Say "Hide satellite Rocky"
Say "Hide satellite Bullwinkle"
Say "Ahead 10 minutes"
Say "Animate start"
Say "Backup six minutes"
Say "Animate start"
Say "Animate pause"
Say "Display satellite Rocky"
Say "Display satellite Bullwinkle"
Say "Animate reset"
Say "Minimize all STK views"
Say "End" (Wait for the statement to appear before saying "OK")
Say "OK"
Say "Did the anomaly occur while the satellite passed through an area of hazardous space weather or debris"? (Wait for the statement to appear before saying "OK")
Say "OK"
Say "Did any other satellite's anomalies occur near the same area of space"? (Wait for the statement to appear before saying "OK")
Say "OK"

Note: This effort is a preliminary step toward a scientific study which will be performed in the future. An experimental plan will be developed to include all aspects of data collection on a scientific level, and experimentation will take place as such. The information gathered in this evaluation will provide insight and direction towards the design and development of that experiment.

Apppendix C: SIDCO Evaluation Scenarios

In order to ensure we collect data that is relevant to space situational awareness, we believe we should run subjects using realistic scenarios (drafted below). In order to do this without getting into sensitive information, I've done some research into what is available in the public domain (see Appendix).

The subjects will observe events happening in STK 3-D windows. One or more satellites will be highlighted (But how?) when a problem is sensed. At this point the subject will start their analysis to answer these questions:

1. Is this a **system problem**? If so, defer to appropriate analyst.
2. Is this a **space weather** incident? If so, report to proper authority.
3. Is this an **attack**? If so, determine the following:
    a. What is the nature of the aggression? Physical, RF, laser, etc.
    b. Has the damage hindered the satellite's ability to perform its mission?
    c. Where is the aggression coming from?
        i. In space or terrestrial?
        ii. Pin-point the location of the aggression.
    d. Have other satellites been affected? This actually might be an indication that it is indeed an act of aggression.
    e. Are other satellites at risk?

Scenario 1: System problem

Either a subsystem has degraded or there is a glitch between the sensor and the ground.
Characteristics: The problem appears to be isolated to one satellite. When the satellite experienced trouble it was not in a location that an attack or turbulent space weather would be expected. The problem appears to be isolated to one subsystem. The satellite's altitude and attitude were not altered in an unexpected manner.

Scenario 2: Space weather

This could appear to be a physical or electromagnetic attack at first so the analyst will need to do careful investigation.
Characteristics: Solar flares, geomagnetic storms, coronal holes, asteroids, comets or other natural occurrences in space were expected. Multiple satellites can have anomalies due to space weather. The satellite's altitude and attitude support such a conclusion (BUT HOW?).

Scenario 3: Attack from a terrestrial weapon system

Event: An enemy high-powered laser tracks and fires upon a US spacecraft. The laser power is directed at the solar panels of the spacecraft. The firing is done while the spacecraft is over enemy territory. The attack is massive and the incident power overloads 80% of the solar panels elements. The US spacecraft is not able to charge its panels. The primary payload shuts down to conserve power for command and control. The spacecraft is able to communicate for 18 more hours and then goes silent.

Characteristics: Ground controllers notice a complete degradation in the solar panel output power. Although communication is possible with the spacecraft, the primary payload shuts down automatically in order to preserve power for command and control. The degradation of the solar panels prevents the spacecraft from charging its batteries. Eventually all communication with the spacecraft is lost within the day.

Scenario 4: Attack from a space weapon system

Event: An enemy microsatellite was launched on small launch vehicle a few months ago. The microsatellite was co-planar with a US spacecraft. Through the initiation of a maneuver, the enemy microsatellite was able to move into close proximity to the US spacecraft. The satellite deploys a metal mesh umbrella in front of (or over) the command and control antenna. The enemy microsatellite flies in formation, until the desired effect has been achieved and then retracts the umbrella, initiates a second maneuver, and departs from the US spacecraft.

Characteristics: Ground controllers are unable to uplink to or downlink from the spacecraft. Repeated attempts to establish communication fail. The spacecraft appears to maintaining attitude and orbit, but over a few weeks the orbit begins to degrade.